(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 July 2001 (19.07.2001)

PCT

(10) International Publication Number
WO 01/51183 A1

(51) International Patent Classification[7]: B01D 59/44, H01J 49/00

(21) International Application Number: PCT/US01/00579

(22) International Filing Date: 8 January 2001 (08.01.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/175,102 7 January 2000 (07.01.2000) US

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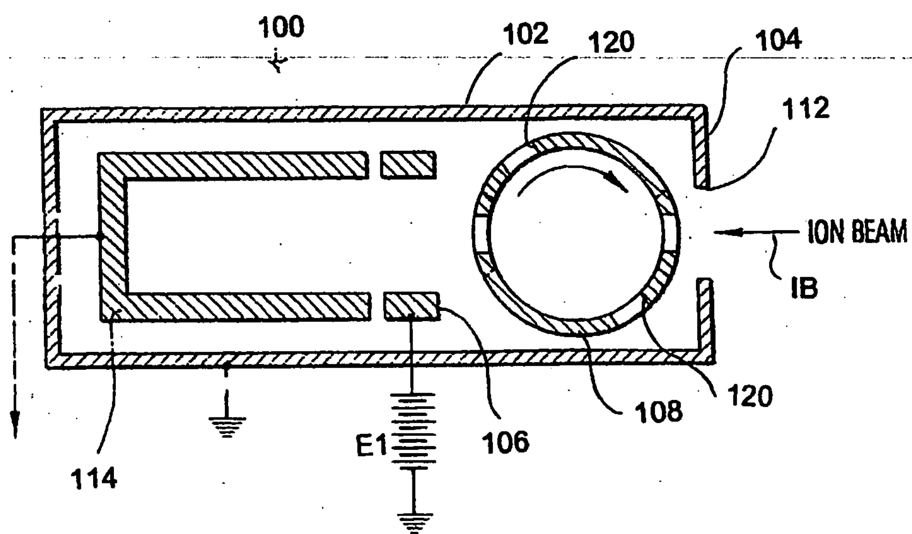
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ENHANCED FARADAY CUP FOR DIAGNOSTIC MEASUREMENTS IN AN ION IMPLANTER



(57) Abstract: An apparatus and method are disclosed for profiling the ion beam (IB) in an ion beam implant system. The apparatus includes an insulating substrate (102) that supports at least one charge-collecting zone defined by a conductive material coupled to the insulating substrate; a mechanism for displacing the ion beam relative to the at least one charge-collecting zone (100) for causing an intercept region of an ion implantation beam to impact the at least one charge-collecting zone; and a mechanism (108) for profiling the horizontal and vertical (x and y-coordinate) ion beam intensity distribution for the ion beam.

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ENHANCED FARADAY CUP FOR DIAGNOSTIC MEASUREMENTS IN AN ION IMPLANTER

RELATED APPLICATION

This application is a non-provisional application that claims the priority of prior provisional application serial number 60/175,102 entitled "SYSTEM AND METHOD FOR ROTATING APERATURE FARADAY CUP FOR MEASURING VERTICAL BEAM PROFILE" filed January 7, 2000, which is hereby incorporated by reference into this application.

FIELD OF THE INVENTION

The present invention is directed to an ion beam implant system, and more particularly is directed to an ion beam profiling system for evaluating the horizontal and vertical (x- and y-coordinate) profile for the ion beam and adjusting the dosage of an ion beam.

BACKGROUND OF THE INVENTION

As is well known in the art, ion implantation is a technique for applying to an atomic ion an amount of energy large enough to cause the atomic ion to penetrate through a surface of a target object to implant the atomic ion therein. An ion-implanting apparatus is designed to carry out this technique and typically includes a vacuum apparatus, an ion-supplying apparatus, and an ion extracting apparatus, a scanning apparatus, an ion-implantation section. The apparatus causes ions emitted from the ion-supplying apparatus to form an ion beam that follows a travel path to the ion implantation section. Within the ion implantation section, silicon wafers are impacted by the ion beam to dope the silicon wafers with a controlled concentration of an impurity to produce a semi-conductor material.

A Faraday cup installed in the ion-implantation section is used to hold secondary electrons generated at the time of ion implantation in the wafer to accurately measure the amount of ions implanted and to profile the ion beam along one coordinate axis to enable adjustment of the ion beam to provide uniform dosage to the wafer. A well-known Faraday cup assembly has the construction shown in FIG. 1. Positive ions, which are extracted by activating the supplied gas, are accelerated to a point where they are implanted into a wafer 14 mounted to a disc 12 through Faraday cup assembly 10. Disc 12 is connected to a net current meter 16. The Faraday cup assembly 10 is formed with a backward bias power supply source 17 for suppressing the generation of secondary ions, a beam current meter 18 for measuring total current flowing toward the backward bias power supply source 17, and a net current meter 16. Therefore, the amount of current resulting from the supply of a negative potential toward disc 12, which is equal to the quantity charged in order to implant the positive ions into wafer 14, is measured in net current meter 16. Also, the amount of current obtained by summing the current resulting from the negative potential that migrates to set a neutralizing environment for the Faraday cup assembly 10 and the current flowing through net current meter 16 is measured in beam current meter 18.

By way of background, the prior art includes several classes of implanters. One employs an ion beam that is swept in two dimensions across a stationary semiconductor wafer or other target being irradiated with the ion beam. In alternate designs, the wafers are moved through the ion beam. These latter systems include ion beams having a relatively large diameter, often as large as the diameter of the wafer that the ion beam impacts. Another implanter employs a hybrid system in which the wafer is moved along one coordinate direction while the ion beam is moved along the other coordinate direction.

The first type of implanter is embodied in a typical medium current instrument. A single wafer is implanted by electrostatically scanning the ion

beam by two orthogonal pair of sweep plates or other beam deflectors. The alternate design implanter in which the wafer is scanned through the ion beam is embodied in typically high current instruments employing an apertured spinning scanning disk.

For utilizing the dose uniformity control and neutralizing features of a Faraday cup, the electron beam is made to scan across an opening of the cup for producing a flow of current from the latter, or alternatively, the cup is rotated such that the ion beam scans across the opening. More particularly, as the beam begins to cross the leading edge of the cup opening, current begins to flow from the cup and increases in value as more of the cross-sectional area of the beam is encompassed by the cup opening. For spot beams, the width of a conventional cup opening is larger than the cross-sectional width of the beam. As more of the cross-sectional width of the beam crosses over the leading edge of the cup opening, more of the beam cross-sectional area is encompassed by the cup opening resulting in an increased current flow from the cup. Assuming that the value of the current reaches a maximum when the cross-sectional width of the beam has completed crossing the leading edge of the cup opening, the cross-sectional width of the beam can be determined from the scanning rate of the beam and the time required for the current to change from a minimum to a maximum value. Current density and energy density are readily determined from the maximum current value that is measured.

A problem with the ion beam profile information provided by present day Faraday cups is that it is only obtains information for the ion beam along one coordinate axis (such as its horizontal axis). Consequently, the uniformity control for the ion beam dosage is limited to this one coordinate axis of the ion beam. It is desirable that ion beam profile information be readily available for two dimensions (x and y) of the ion beam. This would enable rapid dosage adjustments to be made for the entire ion beam profile.

Further, as is well known, ion beam parallelism with the axis of the Faraday cup is important since variation in the orientation angle results in inconsistent penetration of the wafer. For example, if the length of a strip-shaped cross-section of a ribbon beam is parallel to the leading edge of the cup opening, that is, if the orientation angle is 0° so that the ribbon beam approaches the leading edge of the cup opening in a direction parallel to the direction of the cross-sectional width, then the wafer is impacted as expected. However, when the orientation angle is such that the strip beam is skewed relative to the leading edge of the cup, the wafer is impacted in areas not intended, which may result in undesirable channeling of the ions in the wafers. As can be readily appreciated, this inconsistent implantation of ions is undesirable. Therefore, changes in the orientation angle can cause different and inaccurate current and energy densities to be measured with a conventional Faraday cup.

Thus, what is needed is a Faraday cup avoids channeling of ions into the wafer by insuring that the ion beam is parallel to the axis of the Faraday cup and, further, a Faraday cup that enables the profiling of the ion beam in both the x- and y-coordinate. For ion implanters in which the Faraday cup is translated through a ribbon or strip beam, the y-profile of an ion beam is important since the height of the ion beam needs to be known to insure that the beam does not extend vertically beyond the opening of the Faraday cup, that this heights remains consistent throughout the length of the beam, and further to determine that the current density remains consistent near the upper and lower edges of the beam.

The disclosure of U.S. Patent Nos. 5,198,676, 4,980,562 and 4,922,106 are incorporated by reference as if fully set forth herein.

DISCLOSURE OF THE INVENTION

An apparatus constructed in accordance with the present invention provides a Faraday cup with vertical ion beam profiling capability for monitoring

beam intensity and further provides beam parallelism measurements. Different geometries for the Faraday cups of the present invention are disclosed.

The ion beam implantation apparatus for monitoring ion beam intensity distributions horizontally and vertically for an ion beam comprises an insulating substrate that supports at least one charge-collecting zone defined by a conductive material coupled to the insulating substrate, a scanning means for causing an intercept region of an ion implantation beam to impact the at least one charge-collecting zone; and a profiling means for profiling the horizontal ion beam intensity distribution and the vertical ion beam intensity distribution for the ion beam.

In one embodiment, the charge-collecting zone is a Faraday cup and includes an electrode, and the profiling means is a cylindrically shaped revolving conduit mounted within the Faraday cup. The revolving conduit includes two opposing helically shaped slots to allow a circumferentially varying vertical portion of the ion beam to pass through the opposing helically shaped slot and impact the electrode of the Faraday cup to determine the vertical ion beam intensity distribution and two opposed vertical slots to allow a vertical slice of the ion beam to pass through vertical slot and impact the electrode of the Faraday cup to determine the horizontal ion beam intensity distribution of the ion beam.

In an alternative embodiment of the present invention, the at least one charge-collecting zone is a Faraday cup and includes a first electrode for receiving the ion beam, and the profiling means comprises a pair of vertically spaced electrode elements for receiving secondary electrons generated by the ion beam striking a rear portion of the Faraday cup. The distribution of the secondary electrons proving a profile of ion beam intensity distribution.

The method of monitoring the vertical and horizontal ion beam intensity of an ion beam comprising the steps of: a) arranging at least one charge-collecting

conductive zones on an insulating substrate; b) arranging a cylindrically shaped revolving conduit between the charge-collecting zones and the ion beam in the path of the ion beam, the cylindrically shaped revolving conduit having at least one helically shaped slot to allow circumferentially varying portions of the ion beam to pass through the helically shaped slot and impact the electrode of the Faraday cup and at least one vertical slot to allow a vertical slice of the ion beam to pass through vertical slot and impact the electrode of the Faraday cup, c) displacing the substrate relative to the ion beam to allow different regions of the ion beam to impinge upon the at least one charge-collecting conductive zones; d) determining the vertical ion beam distribution of the ion beam by storing a charge signal related to the charge of each circumferentially varying vertical portions of the ion beam, and e) determining the horizontal ion beam distribution of the ion beam.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic overview of a prior art Faraday cup design;

FIG. 2 is a section view showing an ion beam profiler suitable for monitoring intensity in both the x- and y- coordinates of an ion beam;

FIG. 3 is a perspective view of the revolving ion beam conduit of the present invention; .

FIG. 4 is a section view of an alternative embodiment of the present invention wherein the electrode of the Faraday cup is placed internally of the revolving ion beam conduit;

FIG. 5 is a section view os a second alternative embodiment of the present;

FIG. 6 is a side elevational view of the second alternative embodiment of the present invention; and

FIG. 7 is a third alternative embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A Faraday cup structure for profiling both coordinates of an ion beam according to an embodiment of the present invention is generally indicated in FIG. 2 at 100. A Faraday cup is a charge-collecting zone used in ion implanter apparatus. The Faraday cup structure 100 includes a housing 102 of electrically isolating material that has an inlet 112 formed in a surface 104 thereof, an electrode 114 of electrically conductive material, a suppressor electrode 106 and a revolving ion beam conduit 108.

In one embodiment, the housing 102 is shaped like a rectangular casing enclosing an area of ion beam immediately before the wafer. The housing may be constructed of a refractory metal such as, for example, molybdenum, tungsten or platinum and should have a melting point of a sufficiently high value so that it

will not begin to melt when cup structure 100 is scanned by beam IB. Housing 102 is provided so as to electrically isolate the cup from ion beam IB except at electrode 114. Housing 102 is desirably connected to ground or earth potential to prevent a negatively charged build-up as ion beam IB scans cup structure 100 or, alternatively, cup structure is rotated through ion beam IB. More specifically, as beam IB scans cup structure 100, electrons issuing from the beam and tending to be retained in electrically isolating housing 102 near the outer portion thereof are drawn off to ground.

Suppressor electrode 106 is located between electrode 114 and inlet 112 of the Faraday cup 100. A suppressing voltage is added to the suppressor element and the ground by power source E1. The positive terminal of power source E1 is connected to a current measuring line, which extends from Faraday cup 100, and earthed via a detector section that detects beam current for single wafer ion implanters. As a wafer is shot by ion beam IB and its surface energy becomes high, secondary electrons are emitted. If the secondary electrons escape from Faraday cup 100, positive charges associated with these secondary electrons are counted thereby leading to inaccurate measure of ions implanted. Suppressor electrode 106 suppresses these secondary electrons from leaving Faraday cup 100. Suppressor electrodes are well known in the art and no further discussion will be provided herein.

The revolving ion beam conduit 108 is preferably positioned adjacent inlet 112 of housing 102 and is centered such that the axis of rotation for conduit 108 is at the midline of Faraday cup 100. Conduit 108 is formed with a pair of opposing helically shaped slots 120 as shown in Fig. 3, which share a common midpoint along the longitudinal midline of conduit 108 and extend in opposite directions therefrom. This configuration is commonly referred to as a double helix. Conduit 108 is further formed with a pair of opposed, longitudinally extending slots 122.

Conduit 108 is rotated by mechanical means, as is well known in the art,

such as a stepper motor, which imparts rotational energy to a gear that in turn rotates conduit 108 about its longitudinal axis (which is transverse to the direction of ion beam IB). Preferably, conduit 108 rotates at approximately at approximately 1,200-1,800 revolutions per minute. An optical encoder may be used to provide an indication of the orientation of the conduit.

It will be understood that the y-coordinate profiling slots may have other configurations without departing from the scope of this invention.

Operation of the Faraday cup structure 100 of the present invention is as follows: ion beam IB is relatively displaced across cup structure 100 slowly so that ion beam scans inlet 112. As ion beam impacts the revolving conduit 108, a portion of ion beam IB in the vertical (or y-)coordinate is able to pass through both helically shaped slots 120 depending on the angular orientation of the conduit 108 and contact electrode 114, while the remaining portion of the ion beam is blocked by either the external or internal housing of conduit 108. As ion beam IB impacts electrode 114 of cup structure 100, it produces a current flow therealong. Electrode 114 is connected to an appropriate processing circuit (not shown) in which the current flow from electrode 114 is measured and values of the current density and current distribution are determined from the measured current flow, whereupon the dosage may be varied in accordance with the determined current density, current distribution and beam width in order to maintain desired values for such
characteristics of ion beam. As the conduit continues to rotate, the remaining portions of the vertical (or y-) coordinate is allowed to pass through to electrode 114 and thereby a beam profile for the y-coordinate is obtained.

The horizontal (or x-) coordinate is still measured as before since an entire vertical slice passes through upon alignment of the vertical slots 122. The Faraday cup of the present invention may be stopped such that the vertical slots 122 are in alignment with the ion beam and the Faraday cup 100 may be used for

measuring the precise vertical slice of the ion beam.

As will be readily appreciated, when ion beam is made to scan across Faraday cup structure 100 and impacts the housing of conduit 108, no current flows from cup structure 100 until ion beam passes through slots 120 and 122 and impacts electrode 114.

The rotating conduit 108 provides a sample for ion beam current density and scans along the vertical coordinate twice with each rotation. Thus, the number of samples desired divided by two (the number of samples per revolution) provides the number of revolutions required, which may be divided by the scan rate of the beam to determine the revolution per second required for the sample.

In an alternative embodiment of the Faraday cup shown in Fig. 4, the Faraday cup 100' includes a cylindrical housing 102' of electrically isolating material that has an inlet 112' formed therein, an electrode 114' of electrically conductive material, a suppressor electrode 106' and a revolving ion beam conduit 108'. The housing 102' may be constructed of a refractory metal such as, for example, molybdenum, tungsten or platinum and should have a melting point of a sufficiently high value so that it will not begin to melt when cup structure 100' is scanned by ion beam IB. Housing 102 is provided so as to electrically isolate the cup from ion beam IB except at electrode 114'. Housing 102' is desirably connected to ground or earth potential to prevent a negatively charged build-up as ion beam IB scans cup structure 100' or, alternatively, cup structure is rotated through ion beam IB . More specifically, as beam IB scans cup structure 100', electrons issuing from the beam and tending to be retained in electrically isolating housing 102' near the outer portion thereof are drawn off to ground.

Suppressor electrode 106' is located on the inlet side of the Faraday cup 100 and between inlet 112' and the electrode 114'. A suppressing voltage is added to the suppressor element and the ground by power source E1'. The positive terminal of power source E1' is connected to a current measuring line, which

extends from Faraday cup 100', and earthed via a detector section that detects beam current for single wafer ion implanters.

As a wafer is shot by ion beam IB and its surface energy becomes high, secondary electrons are emitted. If the secondary electrons escape from Faraday cup 100', positive charges associated with these secondary electrons are counted thereby leading to inaccurate measure of ions implanted. Suppressor electrode 106' suppresses these secondary electrons from leaving Faraday cup 100'.

The revolving ion beam conduit 108' is preferably positioned adjacent inlet 112' of housing 102' and is formed with a pair of opposing helically shaped slots (not shown), as explained in the first embodiment. Conduit 108' is further formed with a pair of opposed, longitudinally extending slots (not shown).

Conduit 108' is rotated by mechanical means, as is well known in the art, such as a stepper motor, which imparts rotational energy to a gear that in turn rotates conduit 108 about its longitudinal axis (which is transverse to the direction of ion beam IB). Preferably, conduit 108 rotates at approximately at approximately 1,200-1,800 revolutions per minute. An optical encoder may be used to provide an indication of the orientation of the conduit.

In operation, this alternative embodiment of the Faraday cup operates similarly to the first embodiment. However, in the alternative embodiment, only one sample is for the y-coordinate provided per revolution of the cylinder.

BEAM PARALLELISM

As previously noted, the strip-shaped cross-section of a ribbon ion beam may form an orientation angle with respect to inlet 112 . When the orientation angle is 0°, that is, the inlet 112 and the strip-shaped cross-section of beam are parallel with each other, the ions properly strike electrode 114 and wafer. However, if the orientation angle is greater than 0°, such as 10°, the implantation of the ions into the wafer will be insconsistent due to channeling of the ions. A Faraday cup

structure according to the present invention is shown in Figs. 5-7 and generally indicated at 200. The Faraday cup structure includes a housing 202 of electrically isolating material that has an inlet 212 formed in a surface 204 thereof, an electrode 214 of electrically conductive material, a suppressor electrode 206, a parallelism electrode 210 and a secondary coordinate uniformity electrode 216.

The housing 202 is shaped like a rectangular casing enclosing an area of ion beam immediately before the wafer. The housing may be constructed of a refractory metal such as, for example, molybdenum, tungsten or platinum and should have a melting point of a sufficiently high value so that it will not begin to melt when cup structure 200 is scanned by beam IB. Housing 202 is desirably connected to ground or earth potential to prevent a negatively charged build-up as ion beam IB scans cup structure 200 or, alternatively, cup structure is rotated through ion beam IB . More specifically, as beam IB scans cup structure 200, electrons issuing from the beam and tending to be retained in electrically isolating housing 202 near the outer portion thereof are drawn off to ground.

Suppressor electrode 206 is located adjacent the inlet 212 of the Faraday cup 200. A suppressing voltage is added to the suppressor element and the ground by power source E1. The positive terminal of power source E1 is connected to a current measuring line, which extends from Faraday cup 200, and earthed via a detector section that detects beam current for single wafer ion implanters. The suppressor electrodes operate the same as previously described. It will be understood by those skilled in the art that magnetic suppression may be used without departing from the scope of the present invention.

Parallelism electrode comprises two electrode elements 218 and 220. These electrodes would not be contacted the ion beam if the beam is parallel with the axis of the Faraday cup. However, if the ion beam diverges, current will flow from the particular electrode to a current meter attached to these electrodes to provide an indication that the entire beam is not traveling in a parallel manner.

Preferably the electrode elements 218 and 220 are negatively biased such that they do not collect secondary electrons.

As shown in Figs. 5 and 7, the vertical profile for such Faraday cup 200 comprises a series of vertically spaced electrode elements, generally indicated at 224, for providing information pertaining to secondary coordinate uniformity. Each electrode is connected to a power source for supplying a voltage. The electrode elements 224 detect secondary electrons generated when the ion beam strikes the rear of the cup. Preferably, the electrode elements are not struck by the ion beam and thus do not require cooling. These electrodes are positively biased to attract the secondary ions. The series of electrode elements are positioned in the Faraday cup structure such that each electrode element only attracts secondary electrons from one vertical position on the cup structure.

The vertical beam profile generated by the vertically spaced electrode elements is useful in determining the amount of overscan required by the wafer in the y-coordinate. It is also useful in determining whether the ion beam is too large in the y-coordinate and is being masked by apertures that could result in sputtering of materials into the wafer.

It will be appreciated from the foregoing, that the present invention provides a new and improved method and apparatus for measuring the energy density, current

density, width and current distribution of an ion beam in both the x- and y-coordinates and enable the accurate measurement for the above-noted beam parameters with a determination of a parallel ion beam configuration.

Having specifically described illustrative embodiments of the invention with reference to the accompanying drawings, it is to be understood that the invention is not

limited to those precise embodiments and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope

and spirit of the invention as defined in the appended claims.

CLAIMS

What is claimed is:

1. An ion beam implantation apparatus for monitoring ion beam intensity distributions horizontally and vertically for an ion beam comprising:

an insulating substrate that supports at least one charge-collecting zones wherein the at least one charge-collecting zone is defined by a conductive material coupled to the insulating substrate;

scanning means for causing an intercept region of an ion implantation beam to impact the at least one charge-collecting zone; and

a profiling means for profiling the horizontal ion beam intensity distribution and the vertical ion beam intensity distribution for defining an intensity mapping of the intercept region of the ion beam.

2. The apparatus of claim 1 wherein the at least one charge-collecting zone is a Faraday cup and includes an electrode, and wherein the profiling means comprises a revolving conduit having at least one helically shaped slot to allow circumferentially varying portions of the ion beam to pass through the helically shaped slot and impact the electrode of the Faraday cup.

3. The apparatus of claim 1 wherein the at least one charge-collecting zone is a Faraday cup and includes an electrode, and wherein the revolving conduit includes two opposing helically shaped slots to allow a circumferentially varying vertical portion of the ion beam to pass through the opposing helically shaped slot and impact the electrode of the Faraday cup.

4. The apparatus of claim 3 wherein the revolving conduit is mounted within the Faraday cup.

5. The apparatus of claim 2 wherein the revolving conduit further comprises at least one vertical slot to allow a vertical slice of the ion beam to pass through vertical slot and impact the electrode of the Faraday cup to determine the horizontal ion beam distribution of the ion beam.

6. The apparatus of claim 5 wherein the revolving conduit comprises two opposed vertical slots to allow a vertical slice of the ion beam to pass through vertical slot and impact the electrode of the Faraday cup to determine the horizontal ion beam distribution of the ion beam.

7. The apparatus of claim 1 wherein the at least one charge-collecting zone is a Faraday cup and includes an electrode, and wherein the profiling means comprises a cylindrically shaped revolving conduit having at least one helically shaped slot to allow circumferentially varying portions of the ion beam to pass through the helically shaped slot and impact the electrode of the Faraday cup to determine the vertical ion beam distribution of the ion beam and at least one vertical slot to allow a vertical slice of the ion beam to pass through vertical slot and impact the electrode of the Faraday cup to determine the horizontal ion beam distribution of the ion beam.

8. The apparatus of claim 7 wherein the revolving conduit is cylindrically shaped and is located within the Faraday cup and wherein the electrode of the Faraday cup is mounted within the cylindrically shaped Faraday cup.

9. The apparatus of claim 1 wherein the at least one charge-collecting zone is a Faraday cup and includes an electrode, and wherein profiling means is a revolving conduit mounted within the Faraday cup, the revolving conduit being

cylindrically shaped and including two opposing helically shaped slots to allow a circumferentially varying vertical portion of the ion beam to pass through the opposing helically shaped slot and impact the electrode of the Faraday cup to determine the vertical ion beam intensity distribution and two opposed vertical slots to allow a vertical slice of the ion beam to pass through vertical slot and impact the electrode of the Faraday cup to determine the horizontal ion beam intensity distribution of the ion beam.

10. The apparatus of claim 1 wherein the at least one charge-collecting zone is a Faraday cup and includes a first electrode for receiving the ion beam, and wherein the profiling means comprises a pair of vertically spaced electrode elements for receiving secondary electrons generated by the ion beam striking a rear portion of the Faraday cup.

11. The apparatus of claim 10 wherein the pair of vertically spaced electrode elements are positioned adjacent the rear portion of the Faraday cup.

12. The apparatus of claim 11 further comprising a pair of parallelism electrodes for determining the divergence of the ion beam in the Faraday cup, the parallelism electrodes producing a current flow upon being impacted by the ion beam to thereby indicate the divergence of ion beam.

13. The apparatus of claim 12 wherein the parallelism electrodes are negatively biased to repel secondary electrons generated by the ion beam striking a rear portion of the Faraday cup.

14. A method of monitoring the vertical and horizontal ion beam intensity of an ion beam comprising the steps of:

a) arranging at least one charge-collecting conductive zones on an insulating substrate;

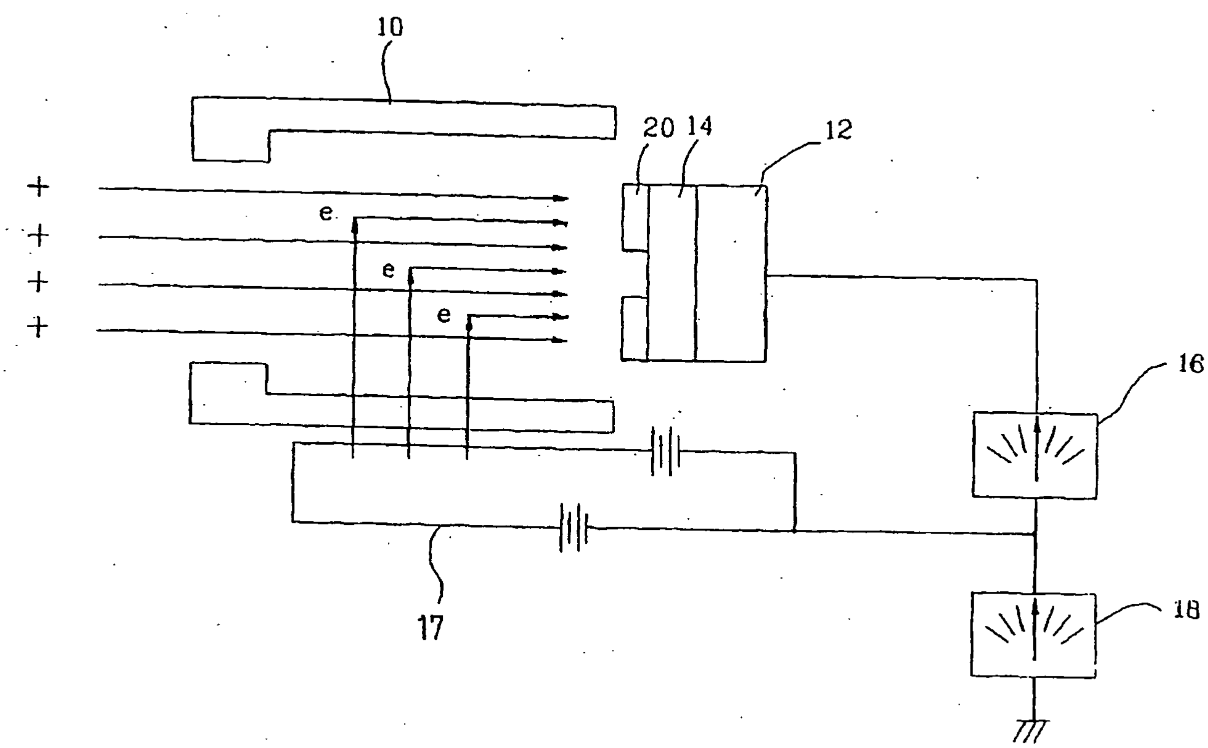
b) arranging a cylindrically shaped revolving conduit between the charge-collecting zones and the ion beam in the path of the ion beam, the cylindrically shaped revolving conduit having at least one helically shaped slot to allow circumferentially varying portions of the ion beam to pass through the helically shaped slot and impact the electrode of the Faraday cup and at least one vertical slot to allow a vertical slice of the ion beam to pass through vertical slot and impact the electrode of the Faraday cup,

c) displacing the substrate relative to the ion beam to allow different regions of the ion beam to impinge upon the at least one charge-collecting conductive zones;

d) determining the vertical ion beam distribution of the ion beam by storing a charge signal related to the charge of each circumferentially varying vertical portions of the ion beam, and

e) determining the horizontal ion beam distribution of the ion beam.

FIG 1
(PRIOR ART)



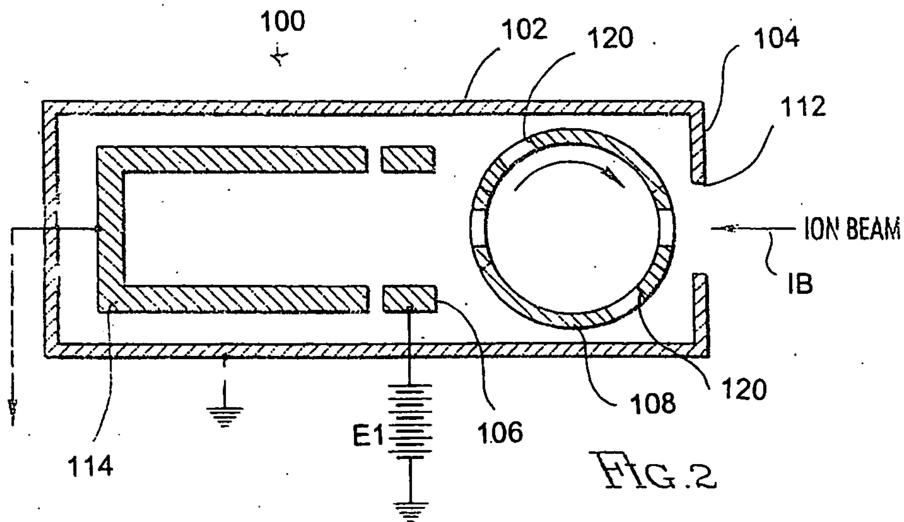

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FIG. 2

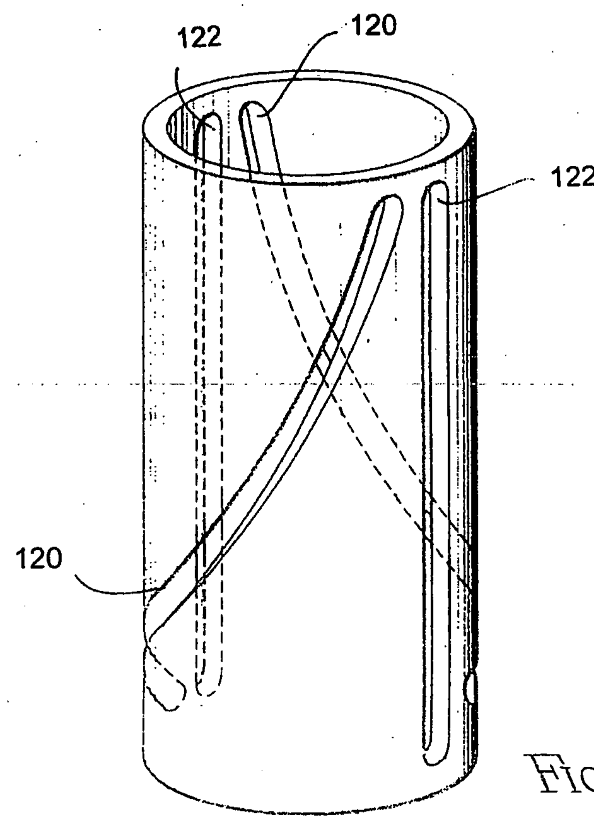
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FIG. 3

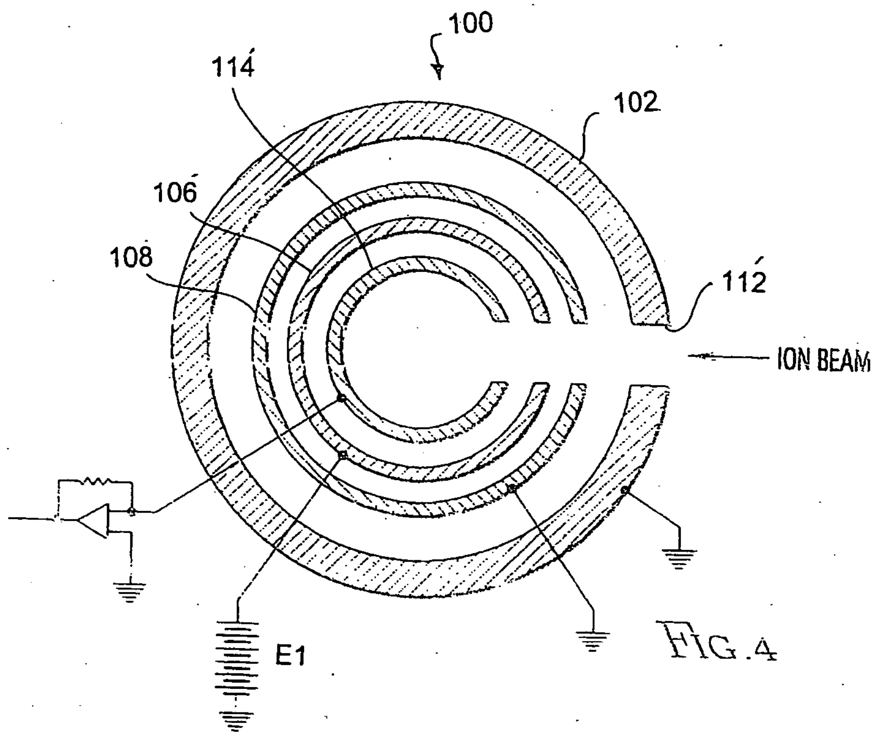

FIG. 4

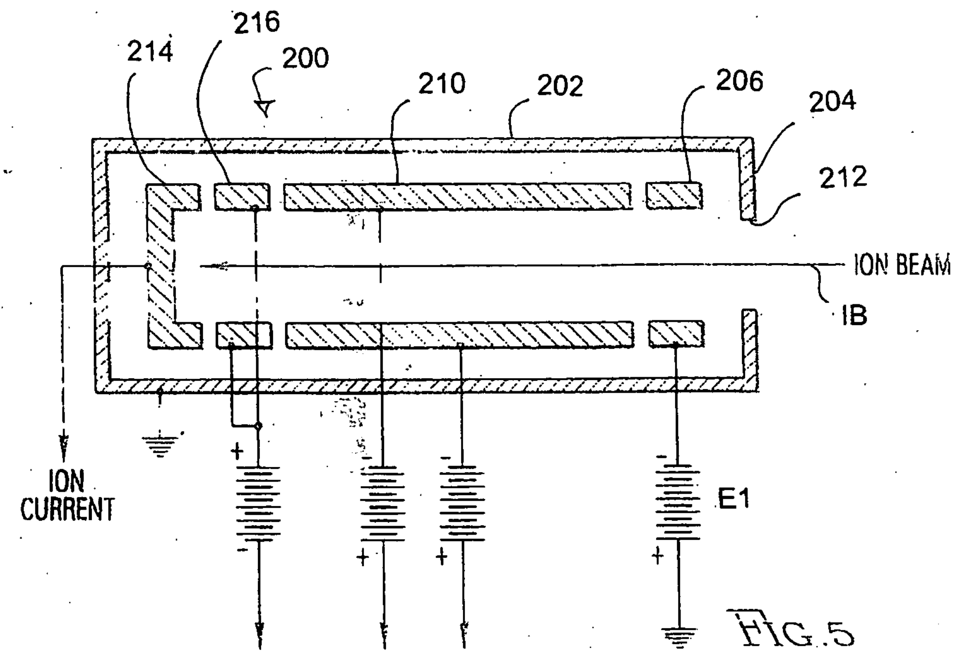
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FIG.5

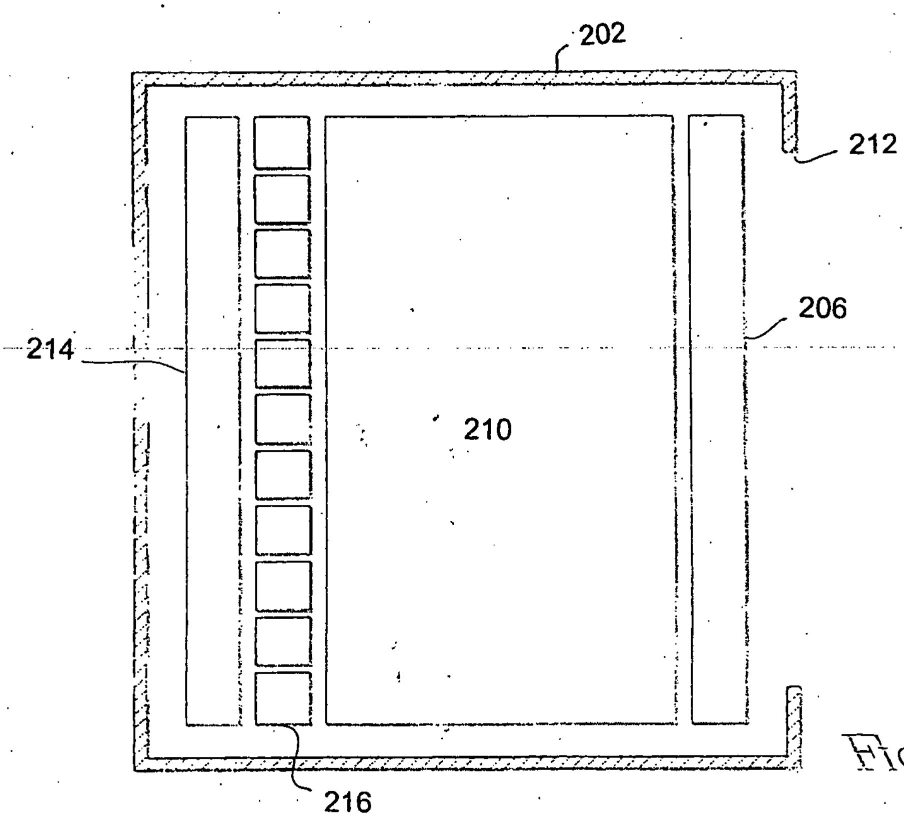
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FIG.6

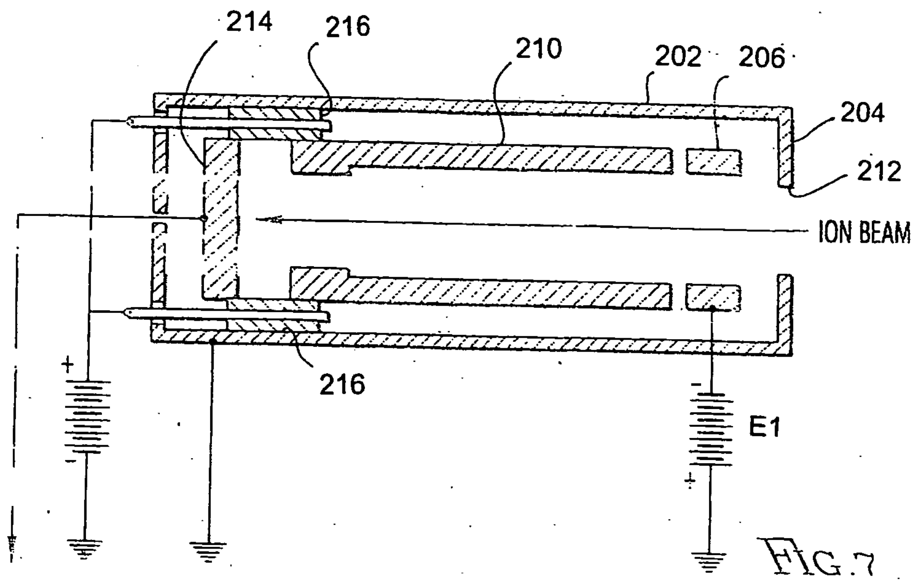

FIG.7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/00579

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B01D 59/44, H01J 49/00
US CL :250/492.3
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 250/492.3

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,198,676 A (BENVENISTE et al.) 30 March 1993 (30.03.1993), Column 1 Line 51 through Column 2 Lline 27, Also Claim 1.	1, 14
Y	US 5,738,985 A (MILES et al.) 14 April 1998 (14.04.1998), See entire document.	1, 14
A, P	US 6,049,220 A (BORDEN et al.) 11 April 2000 (11.04.2000), see entire document.	1, 2, 5
A, E	US 6,175,416 B1 (MARIS et al.) 16 January 2001 (16.01.2001), see entire document.	1-14

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 FEBRUARY 2001	13 APR 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Sharon S. Hoppe TERESA ARROYO Telephone No. (703) 308-0956